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*The Bulletin is published by The Institute of
Physics for circulation to its members.*

Notices to Members

Institute Dinner

The arrangements for the Institute's first Annual Dinner, to be held next year, have been changed from those announced in the August *Bulletin*. The dinner will now be held on Wednesday, March 26 (instead of 25 as previously intended) and will be at the Savoy Hotel, London. It is hoped that there will be wide support for this function from members and their ladies.

Conference on Nuclear Fuel Cycles

The Institute has arranged a three-day conference on Nuclear Fuel Cycles to be held at The Institution of Civil Engineers on January 15, 16 and 17, 1958. Full details will be available shortly. Members who would like to receive these should communicate with the Deputy Secretary.

Institute's Journals

There will be no change next year in the reduced rates to members for Institute journals. It will be assumed that all 1957 subscriptions are to be renewed in 1958 unless members wishing to make any alterations notify the Secretary before the end of the year.

Newton's Conception of Scientific Method

By A. C. CROMBIE

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UNDERSTANDING THE HISTORY OF SCIENTIFIC THOUGHT

COMMENTING on the history of scientific thought, Auguste Comte in his *Cours de Philosophie Positive* (1830 ; Première leçon) made a risky but perhaps not entirely invalid distinction between what a scientist says he is doing in his theoretical and experimental inquiries, and what he must have been "really" doing in order to make the contributions he does. According to Comte, what all successful scientists have really been doing, in spite of anything they might have said to the contrary in describing their objectives and methods, was acting on the principles of positivist philosophy. The founders of positivism as a conscious philosophy of science were according to Comte, Francis Bacon, Descartes, and Galileo, but, as his friend J. S. Mill put it in his *Auguste Comte and Positivism* (2nd ed., London, 1866, p. 7) : "The true doctrine was not seen in its full clearness" by them. "It was, however, apprehended with considerable correctness by Newton." The philosophy of science which Comte attributes to Newton was summarized very clearly by Mill as follows : "The fundamental doctrine of a true philosophy, according to M. Comte, and the character by which he defines Positive Philosophy, is the following :—We have no knowledge of anything but phenomena ; and our knowledge of phenomena is relative, not absolute. We know not the essence, nor the real mode of production, of any fact, but only its relations to other facts in the way of succession or of similitude. These relations are constant ; that is, always the same in the same circumstances. The constant resemblances which link phenomena together, and

the constant sequences which unite them as antecedent and consequent, are termed their laws. The laws of phenomena are all we know respecting them. Their essential nature, and their ultimate causes, either efficient or final, are unknown and inscrutable to us.

"M. Comte claims no originality for this conception of human knowledge. He avows that it has been virtually acted on from the earliest period by all who have made any real contribution to science, and became distinctly present to the minds of speculative men from the time of Bacon, Descartes, and Galileo, whom he regards as collectively the founders of the Positive Philosophy" (*ibid.*, p. 6).

In Comte's view—and Mill certainly agreed with it—the real object of science had always been "savoir, pour prévoir," prediction to give control. "This needed only knowledge of sequences, not of the inmost nature." The persistent belief in the possibility of knowledge beyond knowledge of the laws of sequences was based on a failure to recognize that such knowledge was not only unattainable but unnecessary. Here he shows the influence of Hume.

The great opponent of Comte and Mill in the controversies of the period was William Whewell, Master of Trinity College, Cambridge, and author of the first full-scale English works on the history of science and the philosophy of science. Strongly aware of the role played by theories and hypothetical construction in the development of a science, a result of the influence of Kant, Whewell, in his *Philosophy of the Inductive Sciences* (2nd ed., London, 1847, ii, 320 *sqq.*), rejected Comte's restrictive account of what scientists are "really" doing, and asserted that

inquiry into the "causes" as well as the "laws of phenomena" is not only a legitimate part of science, but is unavoidable. In fact, he said, there is no science in which discussion of "ideas" does not go hand in hand with discoveries of "laws of phenomena." "Ideas" were conceptions of the nature of things, for example the corpuscular structure of matter, the impossibility of action at a distance, the existence and nature of the ether. And, for example in astronomy, "ideas" led to particular formulations of laws; for instance the phenomenal laws of epicycles were made in agreement with the metaphysical principle of the perfection of uniform circular motion; Kepler's mathematical laws of planetary motion were based on his philosophical ideas of harmony and attraction; Newton's theory of gravitation was aimed at being both phenomenal and causal.

Discussing the constant opposition between the schools which respectively made "our senses" and "our ideas . . . the internal element" the principal sources of our knowledge, Whewell claimed that although the current "sensationalist" atmosphere of the seventeenth century "tinged Newton's expressions" it "did not bias his practice" (*ibid.*, p. 295). He claimed that an analysis of Newton's theory of light and colour, and theory of gravitation, shows that Newton was basically concerned with giving a causal account of the transmission of these influences through the medium and that he regarded his mathematical formulations as a step towards such a causal, mechanical explanation based on action by physical contact—hence his speculations about the ether.

In this controversy both Comte and Whewell offered both an interpretation and an evaluation of Newton's philosophy of science, and each claimed Newton as a precedent for himself. Comte's distinction between what a scientist says he is doing and what he is really doing is an evaluation of the scientist's utterances and actions in terms of their acceptability to his own positivism. Similarly, Whewell's distinction between Newton's expressions and his practice is an evaluation in terms of his philosophy of science.

Many other commentaries have been

written on Newton's philosophy of science. The first were criticisms, by the opposing Cartesian school, of the conception of scientific explanation implied by Newton's theories of colour and of gravitation, and criticisms by Leibniz and by Berkeley of Newton's conceptions of causation and of absolute space, time, and motion. These contemporary critics were obviously more concerned with evaluating Newton's contributions than with interpreting them historically, and the same may be said of Kant. It is with Comte and Whewell that historical interpretation really began, and although it is difficult to take Comte seriously as an historian, whereas Whewell was a very good historian, it was Comte's positivist interpretation that formed the picture of Newton for a century, from Brewster to Mach, Dampier and Burt. Under the philosophical influence of Comte and Mill, this picture of Newton was more acceptable than Whewell's. This can be seen, for example, in the misuse of *hypotheses non fingo* as a philosophical slogan; like much of the evidence for the crude positivism which has been attributed to Newton, this is almost invariably quoted out of context.

The presentation of the thought of an age whose pre-suppositions were not identical with our own must always involve some interpretation; the problem for the historian is to distinguish an interpretation of the intentions and conceptions of the past from an evaluation of them in his own terms, and to avoid making an unconscious selection which distorts or simply eliminates genuine aspects of the thought of a scientist like Newton because they are not acceptable or interesting in the modern context or to the historian personally.

And not only is genuine interpretation as distinct from evaluation illuminating historically; it is a contribution to the natural history of scientific thought which is the essential data of the philosophy of science. Without an empirical study of how scientists' minds have in fact worked and how discoveries have in fact been made and theories come into being, philosophical evaluations of science must remain at best purely formal, and at worst mistaken.

If we turn our backs on the evaluation of Newton given by the positivist philosophers and their critics, and look at Newton's own writings, two points obscured by their simplifications immediately stand out: first, the really enormous penetration and subtlety of Newton's mind; and secondly, the manifestation of this in an apparent philosophical opportunism which is nevertheless the product of a consistent philosophical policy in science. In fact Newton's philosophical utterances about science were all made with reference to specific scientific problems and in the course of particular controversies, and it is only in their context that their meaning can be understood. They are not fragments of an uncompleted system; there is no philosophical system in Newton; they are the expressions of a scientific policy which he always practised, but clarified and put into words only piecemeal in the course of specific controversies with Huygens, Leibniz and other critics of his scientific work. The result is that the expression of his policy on different occasions sometimes appears inconsistent and equivocal; hence the possibility of different interpretations if not seen in context; but the policy remained consistently and clearly the same. We can appreciate this policy most easily in Newton's remarks about hypotheses, and his distinctions between hypotheses, occult qualities, causes, laws and axioms, and phenomena, and it is on these distinctions that I shall concentrate.

HYPOTHESES NON FINGO

A new light has recently been thrown on this whole question by Professor Alexandre Koyré, of Paris, who in an important article* has discussed the very revealing changes made in the use of the word "hypothesis" between the first edition of the *Principia* of 1687, and the second edition of 1713 prepared by Roger Cotes, then Plumian Professor of Astronomy at Cambridge.

* A. Koyré, "Pour une édition critique des oeuvres de Newton," *Revue d'histoire des sciences*, Paris, viii, 1955, pp. 19-37; cf. also H. G. Alexander, *The Leibniz-Clarke Correspondence*, Manchester, 1956, and I. B. Cohen, *Franklin and Newton*, Philadelphia, 1956.

Particular exception was taken by Huygens and by Leibniz, to certain phrases in the first edition of the *Principia* which seemed to imply that Newton was putting forward "gravity" as an innate property of matter capable of actively attracting other bodies across the intervening space, that is, as a case of action at a distance. For example: "If two bodies . . . attracting each other with forces inversely proportional to the square of their distance . . ." (i, Prop. LX); "Jupiter and Saturn . . . by their mutual attractions sensibly disturb each other's motions" (iii, Prop. V). Even Newton's friend Richard Bentley misunderstood Newton's intention in these phrases; not unnaturally, since Newton certainly seemed to be saying what his readers thought he was. Newton protested to Bentley: "You sometimes speak of gravity as essential and inherent to matter. Pray, do not ascribe that notion to me; for the cause of gravity is what I do not pretend to know, and therefore would take more time to consider of it." (Newton to Bentley, Jan. 17, 1692-3; *Works of Richard Bentley*, London, 1838, iii, 210.)

"Essential" he used here in the traditional, Aristotelian sense of essential to the existence of matter. "That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of any thing else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man, who has in philosophical matters a competent faculty of thinking, can ever fall into it." (Newton to Bentley, Feb. 25, 1692-3; *ibid.*, p. 211.)

Huygens and Leibniz accused Newton of using the concept of gravity as "a scholastic occult quality,"† an *ad hoc* hypothesis introduced to explain the phenomena of motion, but in fact only a name which explained nothing, and an explanation which, into the bargain, so far as they could see, did involve the absurdity of action at a distance.

† Leibniz to Conti, Nov. or Dec., 1715; cf. *ibid.*, April 9, 1716; both reprinted by Alexander, pp. 184-8.

This was the main ground of their criticism. While appreciating Newton's achievement in giving a mathematical account of planetary motion by means of the inverse square law, they thought his system highly defective in dealing with the physical mechanism bringing the phenomena about. It was a basic part of the philosophy of nature, "the mechanical philosophy," accepted by all scientists in the seventeenth century, including Newton, that all physical action took place by mechanical contact, and it was also universally accepted that a scientific explanation must aim at giving an account of the mechanism by which this occurred.

Newton clarified his position, first in the Latin edition of the *Opticks* (1706) and then in the second edition of the *Principia* (1713), by saying that he used the word "attraction" simply to indicate the observed tendency of bodies to accelerate towards each other, whatever the cause of the acceleration may be; the cause must certainly be investigated, but only after the data, the phenomenal laws, had been ascertained. "What I call attraction may be perform'd by impulse, or by some other means unknown to me. I use that word here to signify only in general any force by which bodies tend towards one another, whatsoever be the cause. For we must learn from the phenomena of nature what bodies attract one another, and what are the laws and properties of the attraction, before we enquire the cause by which the attraction is perform'd." (*Opticks*, 1706, iii, Query 31.) "I here use the word attraction in general for any endeavour whatever, made by bodies to approach each other, whether that endeavour arise from the action of the bodies themselves, as tending to each other or agitating each other by spirits emitted; or whether it arises from the action of the ether or of the air, or of any medium whatever, whether corporeal or incorporeal, in any manner impelling bodies placed therein towards each other." (*Principia*, 2nd ed., 1713, i, Prop. LXIX, Scholium.) To make his position perfectly clear, he added also in 1713 the famous passage in the General Scholium to Book iii: "Hitherto we have explained the phenomena of the heavens and of our sea by the power

of gravity, but have not yet assigned the cause of this power. . . . Gravitation towards the sun is made up out of the gravitations towards the several particles of which the body of the sun is composed; and in receding from the sun decreases accurately as the inverse square of the distances as far as the orbit of Saturn. . . . But hitherto I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypotheses (*hypotheses non fingo*); for whatever is not deduced from phenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction. Thus it was that the impenetrability, the mobility, and the impulsive force of bodies, and the laws of motion and of gravitation, were discovered. And to us it is enough that gravity does really exist, and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and of our sea." (*Principia Mathematica*, Motte-Cajori translation, Berkeley, Calif., 1946.)

Newton's addition of this anti-hypothesis paragraph to the General Scholium, admirable though its intentions may have been, was a great embarrassment to the conscientious Professor Cotes (see below, section 4). Not only was the *Principia* full of hypotheses of the kind apparently rejected—a mechanical one concerning the ether followed in the very next paragraph—but at the beginning of Book iii in the first edition there were printed nine propositions actually called Hypotheses.

Newton rearranged these in the second edition, as Professor Koyré has shown, under the different heading of Rules, Phenomena, and one Hypothesis. Thus Hypotheses I and II became Rules I and II of the "Rules of Reasoning in Philosophy," and Hypothesis III was replaced by a new Rule III. (Rule IV was added in the third edition in 1726.) Hypotheses V-IX became Phenomena I and III-VI, and a new Phenomenon II was added concerning Saturn's rings; these are all observational data concerning the planets.

Only Hypothesis IV remained as an hypothesis, and this was transferred to Proposition X, Theorem X as Hypothesis I: "*That the centre of the system of the world is immovable.* This is acknowledged by all, while some contend that the earth, others that the sun, is fixed in that centre. Let us see what may from hence follow."

In attempting to understand Newton's use of "hypothesis" and other terms in giving an account of the logical structure of science, it is illuminating to note the Euclidean form of the *Principia*. It begins, like Euclid's *Elements*, with a set of Definitions and Axioms (or Laws of Motion), and Books i and ii are largely a mathematical deductive system following from these premisses; it is principally Book iii that makes the system a system of physics, by relating it to the observational data—the phenomena.

Leaving out the Rules, which are not premisses but guides to reasoning in science (for example, Rule I: "We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances"—a form of the principle of economy; Rule II: "Therefore to the same natural effects we must, as far as possible, assign the same causes"—the principle of continuity), we have in the second edition three classes of proposition forming the premisses of the physical system:

- (1) Phaenomena: observational and experimental data;
- (2) Definitions, and Axioms or Laws of Motion;
- (3) One Hypothesis—in the sense of an unproven assumption.

Universal gravitation Newton would discuss in the *Principia* only in terms of the second class: "our purpose is only to trace out the quantity and properties of this force from the phenomena, and to apply what we discover in some simple cases as principles, by which, in a mathematical way, we may estimate the effects thereof in more involved cases. . . . We said, in a mathematical way, to avoid all questions about the nature or quality of this force, which we would not be understood to determine by any hypothesis . . ." (*System of the World*, § 2.)

The "Euclidean" form of offering scientific explanations—the universal form of theoretical sciences—has always contained the problem of how we are to regard the theoretical entities and assumptions which enter into the premisses. Newton's problem—brought forward by the objections to his methods made by his Cartesian critics—was to define the limits of legitimacy for such entities and assumptions, and to sort out the relative strengths of different kinds. With the one exception, "hypothesis" in the second edition of the *Principia* meant, pejoratively, those beyond the pale, or, heuristically, those to be entertained only tentatively as aids to something better. In this way he eliminated most of the equivocal meaning of the word in the first edition. But that is not the end of the story of Newton's use of hypotheses. In fact in developing hypotheses as heuristic aids to scientific investigation he was far more fertile and more varied than any of his contemporaries, and this was undoubtedly in part because he had reached a clearer conception than theirs of the role of hypotheses in science. In his search for the "causes" of gravitation and of the propagation of light and the formation of colours, he made hypotheses with the utmost freedom about the nature of the medium transmitting these influences across space, and he made others about the cohesion of microscopic corpuscles to form hard macroscopic matter and about the nature of chemical affinity; but he always insisted on the important distinction between hypotheses that helped towards the discovery of truth, and fictions, not aimed at this goal, which were pseudo-explanations that could only mislead.

CONCEPTIONS OF HYPOTHESES BEFORE NEWTON

To understand the point of this distinction we must look at the meanings acquired by the term "hypothesis," and at the conceptions of the fundamental propositions and premisses of a science, as developed before Newton.

The deductive form of science set out so elegantly by Euclid was first discussed by Plato, and in the famous account in the *Republic*, Book vi, Plato makes a basic distinction between the status of the first principles

of mathematics, of physics, and of the "highest division" of knowledge (called by Aristotle metaphysics). Students of subjects like geometry and arithmetic, he said, take, as the starting-point of their reasoning, data such as the definitions of figures, angles, numbers, etc., and "having adopted them as hypotheses, they decline to give any account of them, either to themselves or to others, on the assumption that they are self-evident." From these self-evident assumptions they deduce the various conclusions that follow.

In physical science the mind must likewise employ assumptions as first principles, because it cannot rise above them to principles that are certain. These assumptions (or hypotheses) are not self-evident, but are attempts to discover the real forms behind the copies which make up the observable world. Because the latter is only an inaccurate likeness of the real world of the "forms," physics must remain, as Plato put it in the *Timaeus*, only "a likely story."

In the highest kind of knowledge—*episteme*—this restriction does not apply, and there the mind "treats its assumptions, not as first principles, but as hypotheses in the literal sense, things 'laid down' like a flight of steps up which it can mount all the way to something not hypothetical, the first principle of all."

Thus for Plato hypotheses are propositions assumed as the starting-point of a deductive argument, but he envisages their being used where possible—but this does not apply to natural science—to help to discover the truth of what is at first only assumed hypothetically. For Aristotle, similarly, "hypothesis" meant an assumption not calling for proof within the sphere of the special science in which it functions, though it may later be proved, and then it ceases to be an hypothesis (*Posterior Analytics*, i. 2, 11).

From the time of Plato and Aristotle down to that of Newton the term "hypothesis" came, as Professor Koyré has shown, to have three distinct meanings. First, it meant propositions assumed solely as the starting-point of a deductive argument, as in mathematics, for example when Archimedes or Kepler began by letting it be admitted that

an area can be generated by an infinite summation of lines, or when Newton assumed, in order to deduce what followed, that two bodies would attract each other not inversely as the square of the distance, but directly, or inversely as the distance cubed.

Secondly, "hypothesis" meant an assumption or conjecture that we want to test by its consequences, which verify or falsify it—as in physical investigations. For example, Ptolemy's hypotheses of the spherical shape of the heavens and the central position and immobility of the earth were not put forward as arbitrary assumptions; Ptolemy could not prove them, but he tried to make them as plausible as possible; they were the best attempt at the truth which the subject matter and his ability to deal with it allowed. This was the meaning understood by Copernicus when he took as the fundamental propositions of his astronomical system a different set of *principia et assumptiones quas Graeci hypotheses vocant* (*De Revolutionibus*, introduction). In his *Commentariolus de hypothesisibus motuum celestium a se constitutis* he put forward these as *petitiones, quas axiomata vocant*.

Besides these meanings, roughly corresponding to Plato's first two kinds of first principles, "hypothesis" came to acquire a third and quite different meaning. It came to mean an arbitrary assumption, of any kind, put forward in *physical science* solely for the formal purpose of enabling us to deduce and calculate—that is "save"—the phenomena, without asserting that the accuracy of the calculation implies (or does not imply) the ontological truth of the assumptions or the existence of the hypothetical entities assumed. For example, Ptolemy's eccentrics and epicycles were "fictional" devices for calculating the movements of the planets. Osiander, in his preface to *De Revolutionibus*, claimed that the entire Copernican system was a fiction of this kind.

It was in Greek astronomy that the conception of hypotheses as convenient fictions for calculating first developed; thence it led to the conventionalist conception of scientific theories in general. The Greeks devised and developed the method and pattern of scientific thought—observation, hypothesis, deduction

leading to testing by renewed observation. The first hypotheses in astronomy, the concentric spheres of Eudoxus and Callippus, were put forward both as a method of calculating the movements of planets and stars and also as a true account of those movements. Aristotle provided a physical, dynamical explanation of these motions; his system required the heavenly bodies to go in simple circles round the central, static earth. But in the light of later observations this system proved to be inaccurate. The only mathematically accurate alternatives the Greeks managed to devise were the frankly fictional devices of epicycles and eccentrics developed by Hipparchus and Ptolemy. Unable to penetrate the mystery of the true motions of the heavenly bodies, and totally divorced from any system of dynamics and physics (though Ptolemy attempted a remedy in his *Hypotheses of the Planets*), this solution was regarded as unsatisfactory. But no better solution was produced until the seventeenth century, and from Ptolemy to Kepler astronomy remained a science of the "as if." The reuniting of mathematical astronomy with physics (dynamics) by Kepler, Galileo and Newton was the solution of a problem outstanding since the breakdown of the Eudoxan-Aristotelian system.

But the notion of scientific hypotheses as fictions had gone deep. Medieval logicians clearly understood that the phenomena cannot uniquely determine the hypotheses that must "save," or explain, them, for the same conclusions can be deduced from very different premises, and the experimental verification of the consequent does not enable us to affirm the antecedent. From Grosseteste in the thirteenth century to Nifo and Zabarella in the sixteenth, analysts of scientific method developed the view that theories in natural science could not, in the nature of the case, be more than probable conjectures, but they were held to be conjectures of the truth. It was in astronomy itself that the extreme doctrine grew up that, as Osiander put it in his preface to *De Revolutionibus*: "There is no need for these hypotheses to be true, or even to be at all like the truth; rather, one thing is sufficient for

them—that they should yield a calculus which agrees with the observations." It was in accordance with this preface—then believed to be by Copernicus himself—that Cardinal Bellarmine, in his famous letter to Galileo's friend Paolo Foscarini in 1615, advised him and Galileo "to speak hypothetically, *ex suppositione*." And when Galileo was condemned by the Holy Office in 1633 after the publication of the *Dialogue concerning the Two Principal Systems of the World*, he was accused of having only pretended to follow Pope Urban VIII's instruction to present the motion of the earth *quamvis hypothetice*.

Kepler himself developed his second law, the law of areas, in application equally to the systems of Ptolemy, Copernicus, and Tycho Brahe, and showed that from a purely formal, calculating point of view there was no reason to choose between them. The reason for a choice was dynamical, and it was Galileo's main contribution to the debate to insist on the dynamical criterion (though he did not formulate it properly) that made the heliocentric but not geocentric system possible, and thus to begin the reunion of mathematical and physical astronomy.

Descartes also understood this point, and began to develop it in *Le Monde*. But he withheld the work from publication after he heard of Galileo's condemnation, writing in explanation to Mersenne in April, 1634: "Je ne suis point si amoureux de mes pensées, que de me vouloir servir de telles exceptions, pour avoir moyen de les maintenir; et le desir que j'ai de vivre en repos et de continuer la vie que j'ai commencée en prenant pour ma devise: *bene vixit, bene qui latuit*. . . ." Ten years later Descartes' policy of wearing a mask bore its most considerable fruit in the fictional doctrine of scientific hypotheses asserted in the famous declaration in the *Principia Philosophiae*—a doctrine first adopted, as the letter to Mersenne shows, to avoid direct conflict between the cosmology discovered by science and the cosmology alleged by the Inquisitors to have been revealed in the Bible. In the *Principia* (iii, 44) he wrote: "But because the subjects I treat here are not of small importance, and so that I will not be thought too bold if I assert that I have dis-

covered truths which have not been discovered by others, I prefer to decide nothing ; and in order that everyone may be free to think what he pleases, I want what I write to be taken only as an hypothesis (*une hypothèse*) which is perhaps far removed from the truth ; but yet that having been made, I believe that it will have been well made if everything deduced from it agrees completely with the observations. For if that happens it will be no less useful in practice than if it were true, because we can use it equally to set out the natural causes and to produce the effects we desire." This is indeed a revealing indication of the origin of Comte's "savoir, pour prévoir." Descartes went on, in describing his physical system: "I assume here some things that I believe to be false" (*ibid.*, 45), but "their falsity does not prevent that which is deduced from them from being true" (*ibid.*, 47).

NEWTON'S PHILOSOPHY OF SCIENCE

It is against this background that Newton's *hypotheses non fingo* must be understood ; indeed it is likely that Newton's choice of the title *Principia Mathematica* was to give direct point to the polemic he conducted in this work against Descartes and the fictionalist opinions expressed in the *Principia Philosophiae*. Koyré has shown that a protest against proposing the false to deduce the true had already been made in the sixteenth century by Ramus : he said that it was absurd to try to demonstrate the truth of natural things from false causes, and he called for an astronomy without hypotheses (in the sense of fictions). This Kepler claimed to have produced with his laws giving the true planetary motions. Similarly Galileo called for a "philosophical" (physical) and not merely an "arithmetical," calculative astronomy, and claimed that his dynamics could provide it.

Newton's famous remark should thus be translated, not as Motte does, "I make no hypotheses," but "I feign no hypotheses." *Fingere* has both meanings, and in the *Opticks*, which Newton wrote in English, he always used "feign" in similar contexts. He is saying that he does not use fictions. This had a double application.

First, as with Kepler and Galileo, it was a rejection of the "as if" conception of astronomy forced on Ptolemy and his successors by their lack of a better solution, but adopted by some writers later as belonging to the nature of science. Newton asserted, for example : "... how we are to obtain the true motions from their causes, effects, and apparent differences, and the converse, shall be explained more at large in the following treatise. For to this end it was that I composed it." (*Principia*, Definitions, Scholium.)

Secondly, Newton specifically objected to the use in physics of fictions, not simply as the basis of formal calculations, but as entities supposedly real. Here Descartes was the chief offender, and in fact most of the examples Newton gives of hypotheses in the perjorative sense are taken from Descartes' physics. Newton objected to the explanation of observations by supposing the existence, besides the observed phenomena, of something endowed with qualities or structure specially imagined for the purpose, and beyond the control of experiment. And just this was Descartes' explicit method. Descartes conducted his inquiries by constructing hypothetical models, as, for example, in *L'Homme* (the second part of *Le Monde*) he asks us to imagine the body as a statue or machine of clay which operates by the arrangement of its mechanical parts like a clock or mill, or like the machines found in contemporary water-gardens. He then goes on to endow the machine with the parts and properties needed for it to imitate the actions of an actual body—a fruitful device in physiology for analysis of actual bodies, but one that involves the danger, exemplified for us in the recent conception of the brain as a feed-back mechanism, of confusing analogy with identity. Descartes built up his whole cosmology by this method of the analogical model supposedly derived strictly from first principles assumed as true, but in fact loosely derived and containing many details unchecked, or insufficiently checked, by observation ; for example, details of the three original kinds of matter, of the propagation of light and the nature of colour, of the vortices, and so on, on which Newton's work

bore directly. For example Newton showed in the *Principia* (ii) that Descartes' vortex theory would not yield Kepler's laws of planetary motion and so was falsified by observation.

Newton's main problem, in his discussions with Cartesian critics of his own explanation of colour and his law of gravitation, was to establish the independence of his inquiry into mathematical phenomenal laws from that into "causes," that is, into the mechanical processes (or perhaps, he admitted, processes involving immaterial spirits) bringing the phenomena about. The causes he agreed were the ultimate objective, but premature formulations of "causes" could not be used against established laws, a point he first made in the controversies that followed the publication of his "New Theory about Light and Colours" in the *Philosophical Transactions of the Royal Society* in 1671-2. Huygens, for example, wrote of this theory: "Me thinks, that the most important objection, which is made against him by way of *Quaere*, is that, whether there be more than two sorts of colours . . . Neither do I see, why Mr. Newton doth not content himself with the two colours, yellow and blew; for it will be much more easy to find an *hypothesis* of motion, that may explicate these two differences, than for so many diversities as there are of other colours. And till he hath found this *hypothesis*, he hath not taught us, what it is wherein consists the nature and difference of colours, but only this accident (which is certainly very considerable), of their *different refrangibility*." (*Phil. Trans.*, viii (1673) 6086) Newton replied: ". . . to examine how colors may be explain'd *hypothetically*, is beside my purpose. I never intended to shew, wherein consists the nature and difference of colors, but only to shew, that *de facto* they are original and immutable qualities of the rays which exhibit them; and to leave it to others to explicate by mechanical hypotheses the nature and difference of those qualities; which I take to be no difficult matter. But I would not be understood, as if their difference consisted in the different refrangibility of those rays; for, that different refrangibility conduces to their production no otherwise, than by separating the rays whose qualities

they are . . ." (*Phil. Trans.*, viii (1673) 6109).

Newton is not objecting to mechanical hypotheses as such; in fact, not being disposed to take them too seriously in the first instance, where his contemporaries might make one hypothesis, and want to prove it true, he would make a number of different suggestions as aids to further inquiry. The *Opticks* (e.g. Book ii, Part iii, Props. XII-XIII) contains a number of hypotheses to account for the phenomena of light. But Newton did insist that hypotheses should be clearly recognized as such, and further that they are admissible only in so far as they are controlled by experimental tests.

"My design in this book," he began the *Opticks*, "is not to explain the properties of light by hypotheses, but to propose and prove them by reason and experiments: in order to which I shall premise the following definitions and axioms." (There follow definitions of rays of light, angles of incidence, reflection and refraction, simple (homogeneous) and compound (heterogeneous) light and colours; and axioms, for example the statement that the angles of reflection and refraction are in the same plane as the angle of incidence, the law of reflection, Snell's law of refraction, etc.)

In Query 31 of the *Opticks*, in discussing the constitution of matter, Newton made further distinctions: "All these things being consider'd, it seems probable to me, that God in the beginning form'd matter in solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties, and in such proportion to space, as most conduces to the end for which he form'd them. . . .

"It seems to me farther, that these particles have not only a *vis inertiae*, accompanied with such passive laws of motion as naturally result from that force, but also that they are moved by certain active principles, such as that of gravity, and that which causes fermentation, and the cohesion of bodies. These principles I consider, not as occult qualities, supposed to result from the specifick forms of things, but as general laws of nature, by which the things themselves are form'd; their truth appearing to us by phenomena,

though their causes be not yet discover'd. For those are manifest qualities, and their causes only an occult. And the *Aristotelians* gave the name of occult qualities, not to manifest qualities, but to such qualities only as they supposed to lie hid in bodies, and to be unknown causes of manifest effects : such as would be the causes of gravity, and of magnetick and electrick attractions, and of fermentations, if we should suppose that these forces or actions arose from qualities unknown to us, and incapable of being discovered and made manifest. Such occult qualities put a stop to the improvement of natural philosophy and therefore of late years have been rejected. To tell us that every species of things is endow'd with an occult specifick quality by which it acts and produces manifest effects, is to tell us nothing : but to derive two or three general principles of motion from phenomena, and afterwards to tell us how the properties and actions of all corporeal things follow from those manifest principles, would be a very great step in philosophy, though the causes of those principles were not yet discover'd : and therefore I scruple not to propose the principles of motion above-mentioned, they being of very general extent, and leave their causes to be found out."

Newton, like Kepler and Galileo, was trying to make the terms of the inquiry into causes explicit and empirical, to apply to them the same precise and quantitative tests as he applied to laws. A few pages on he reiterates his rejection of hypotheses in the sense of fictions, in a passage describing his method as a whole. "As in mathematics, so in natural philosophy, the investigation of difficult things by the method of analysis, ought ever to precede the method of composition. This analysis consists in making experiments and observations, and in drawing general conclusions from them by induction, and admitting of no objections against the conclusions, but such as are taken from experiments, or other certain truths. For hypotheses are not to be regarded in experimental philosophy. And although the arguing from experiments and observations by induction be no demonstration of general conclusions ; yet it is the best way of arguing

which the nature of things admits of, and may be looked upon as so much the stronger, by how much the induction is more general. And if no exception occur from phenomena, the conclusion may be pronounced generally. But if at any time afterwards any exception shall occur from experiments, it may then begin to be pronounced with such exceptions as occur. By this way of analysis we may proceed from compounds to ingredients, and from motions to the forces producing them : and in general, from effects to their causes, and from particular causes to more general ones, till the argument end in the most general. This is the method of analysis : and the synthesis consists in assuming the causes discover'd, and establish'd as principles, and by them explaining the phenomena proceeding from them, and proving the explanations."

He clarified his position still further in the letter to Cotes in which he gave him instructions concerning the famous phrase, *hypotheses non fingo* : "... as in geometry the word hypothesis is not taken in so large a sense as to include the axioms and postulates, so in experimental philosophy it is not to be taken in so large a sense as to include the first principles or axioms which I call the laws of motion. These principles are deduced from phenomena and made general by induction : which is the highest evidence that a proposition can have in this philosophy. And the word hypothesis is here used by me to signify only such a proposition as is not a phenomenon nor deduced from any phenomena but assumed or supposed without any experimental proof. Now the mutual and mutually equal attraction of bodies is a branch of the third law of motion and how this branch is deduced from phenomena you may see in the end of the corollaries of the Laws of Motion. ...

"And for the preventing exceptions against the use of the word hypothesis I desire you to conclude the next paragraph in this manner (*Quicquid enim ex phaenomenis non deducitur Hypothesis vocanda est. . .*" (Newton to Cotes, March 28, 1713, *Correspondence of Sir Isaac Newton and Professor Cotes*, ed. J. Edleston, London, 1850, pp. 154-5).

So Newton distinguishes the following terms in contemporary scientific usage :

- (1) the "phenomena" ; "effects" : the experimental data.
- (2) "laws and axioms," or "principles," forming the fundamental propositions of a theory. These are "inferred from the phenomena" and afterwards rendered general by induction." They are laws written in the phenomena, but not open to direct inspection but "inferred" or "deduced" from the phenomena by an appropriate mathematical and theoretical analysis of the immediate data. In the case of the law of gravitation Newton used "deduced" in its literal sense, for he showed that just as Kepler's laws could be deduced from it and the laws of motion, so, reciprocally, the inverse square law could be deduced from Kepler's laws, representing the phenomena.
- (3) The "causes of those principles" and laws, i.e. mechanical processes. Like all his contemporaries he believed these to be mechanisms operating by contact, which he hoped science would be able to discover one day : note for example his many speculations on the ether as a medium for propagating of light, gravity, etc., in the *Opticks*, letters to Boyle, and elsewhere.
- (4) "Hypotheses" : propositions assumed but not "inferred" or "deduced" or proved :
 - (a) the admitted hypothesis of the immobility of the centre of universe—a postulate of his system, impossible to deduce from phenomena. Newton hoped that science would one day be able to deduce the real, absolute motions, but he was well aware that it was a long way from empirical means of deciding, for example, whether the centre of the universe was at rest or in uniform rectilinear motion.
 - (b) Heuristic aids to the discovery of causes : for example hypotheses about the ether to explain gravitation, "fits of easy reflection and refraction" to

explain the optical phenomena of colour, interference, etc.

- (c) Illegitimate fictions, proposed *ad hoc* and uncontrolled by experimental tests : for example, Descartes' theory of matter, of vortices (proved false by Newton's quantitative analysis), etc.
- (5) Occult qualities : mere names, for example Aristotelian specific forms.

It was to fictions, and particularly to Descartes' fictions, that Newton objected most among the illegitimate usages, and he especially objected to criticisms of his *laws*, the best established theoretical propositions of science, based on *hypotheses* merely assumed to be true. "In the mean while give me leave, Sir, to insinuate," he wrote in his chilly way in reply to some criticisms by Huygens, "that I cannot think it effectual for determining truth, to examine the several waies by which phenomena may be explained, unless where there can be a perfect enumeration of all those waies. You know, the proper method for *inquiring* after the properties of things is, to deduce them from experiments. And I told you, that the theory, which I propounded, was evinced by me, not by inferring 'tis thus because not otherwise, that is, not by deducing it only from a confutation of contrary suppositions, but by deriving it from experiments concluding positively and directly. . . . And therefore I could wish all objections were suspended, taken from *hypotheses* or any other heads than these two : of showing the insufficiency of experiments to determine these *Quaeres* or prove any other parts of my theory, by assigning the flaws and defects in my conclusions drawn from them ; or of producing other experiments which directly contradict me, if any such may seem to occur. For if the experiments which I urge, be defective, it cannot be difficult to show the defects ; but if valid, then by proving the theory they must render all objections invalid." (*Phil. Trans.*, vii (1672), 5004-5.)* Hence Rule IV,

* He made the same point in his patient reply to Gaston Pardies in the same controversies over his theory of colour, in 1672 : "For the best and safest method of philosophizing seems to be, first diligently to investigate the properties of things and establish

added to the third edition of the *Principia* in 1726 :

"In experimental philosophy we are to look upon propositions inferred by general induction from phenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phenomena occur, by which they may be either made more accurate, or liable to exceptions. This rule we must follow, that the argument of induction may not be evaded by hypotheses."

This is Newton's first and last position in relation to his critics. With great good sense he says that we should take no notice of abstract objections to an argument founded on induction ; it cannot be overthrown by an hypothesis and only further facts of experience (not hypotheses) can force us to modify it or give it up.

We may agree with Newton's scientific policy, yet see why his opponents did not immediately give up their own position. When we come down to details, Newton's point of view was often that all the general theories of his opponents were hypotheses : as Koyré has put it, they form hypotheses, he forms laws. From their point of view, on the other hand, Newton's definitions and laws seemed *a priori* and highly metaphysical. All parties accepted the same "regulative belief" that all action must take place by physical contact, by mechanical, push-pull processes. Naturally they assumed that Newton's law of gravitation implied action-at-a-distance, which was admitted as an

them by experiment, and then to seek hypotheses to explain them. For hypotheses ought to be fitted merely to explain the properties of things and not attempt to predetermine them except in so far as they can be an aid to experiments. If any one offers conjectures about the truth of things from the mere possibility of hypotheses, I do not see how any thing can be determined in any science ; for it is always possible to contrive hypotheses, one after another, which are found rich in new tribulations. Wherefore I judged that one should abstain from considering hypotheses as from a fallacious argument, and that the force of their opposition must be removed, that one may arrive at a maturer and more general explanation." (Newton, *Opera*, ed. S. Horsley, London, 1782, iv, 314-5).

absurdity by Newton as much as the Cartesians. So either the law of gravitation was based on an admitted absurdity, or it was based on an unknowable "occult quality"—the ultimate insult, made by Leibniz in his letters of 1715-16 to the Abbé Conti, a Venetian visiting London, who showed them to Newton.

When Leibniz, Berkeley and other philosophical critics looked further into Newton's philosophy of science, they found its metaphysical aspects even less acceptable than its scientific ones : for example, the conceptions of absolute space and time, of absolute space as God's sensorium, of God's intervention in the machine of the universe. No doubt they would have been even more disconcerted had they been able to read the papers which Newton left behind him at Trinity when he went to London to become Warden, then Master of the Mint in 1696, and set up house with his niece in Jermyn Street.

We must completely misunderstand Newton the man, and we run the risk of missing the essential processes of a mind so profoundly original and individual as his, if we exclude from our field of historical investigation all those influences and interests that may be distasteful to us, or seem to us odd in a scientist. On closer examination it may turn out in fact that it was those very things that were his chief interest and that most profoundly affected his scientific imagination.

During the three or four decades at Cambridge, when his mathematical and scientific victories were being won, Newton's thoughts in fact ranged far beyond the limits prescribed by the restrictive policy of his "mathematical way" in science. In fact the bulk of his writings from this period are not on science at all but on theology, commentaries on the Apocalypse and on the prophecies of Daniel, on Biblical chronology, on alchemy ; the late Lord Keynes estimated that they run into upwards of a million words.† In this matrix the briefer—in comparison—body of the scientific writings on which his reputation rests were produced in short

† Lord Keynes, "Newton, the man," in *Royal Society Newton Tercentenary Celebrations*, Cambridge, 1947.

bursts of scientific activity separated by long periods of apparent revulsion from it.

We must take these voluminous writings into account in judging what Newton's intentions were in science, and when we do it becomes plain that Newton is the very opposite of the austere rationalist or positivist of some later historians and philosophers. It becomes obvious that his main preoccupation was to read the riddle of the whole universe, to disentangle the nature of God, not simply through empirical science—did he not say in the General Scholium that to discourse of God “from the appearances of things, does certainly belong to Natural Philosophy” ?—but principally in the cypher of a tradition now hidden from us but capable of being rediscovered. He expected to find this lost wisdom in the Bible; he was like Kepler and his Rosicrucian controvertist Robert Fludd in one.

When, two years after Voltaire was born, Newton exchanged the life of a “secretive sage,” as Keynes has called him, at Cambridge—he was a silent and touchy man—for that of the man of affairs and public figure in London, he shut up all these writings in a chest at Trinity, where they remained to shock his eighteenth century editor, Samuel Horsley, who omitted all reference to them in his

edition of Newton's *Works*. Eventually they descended through Newton's niece to the Portsmouth family, and are now in large part back in Cambridge. In the chest Newton shut up too the last of the seventeenth century philosophers of nature inspired by theology and by the hope to behold the truth as a whole as well as to puzzle it out in part, the last of the alchemists, the end of the line of Roger Bacon. He emerged in London as the Newton of the age of reason. Charles Lamb later described him as “a fellow who believed nothing unless it was as clear as the three sides of a triangle.” But this is the rationalist elimination of the Newton of the closed chest, and indeed also of the consummate master of the intransigent art of scientific invention and discovery whom we meet in his scientific writings themselves.

“The marble index of a mind forever
Voyaging through strange seas of thought,
alone,”

is Wordsworth's famous comment on Roubiliac's statue in the ante-chapel at Trinity. It is closer to the mark. Geniuses are often strange, and their mental processes impenetrable. In spite of the clarity of his remarks on specific questions of scientific method, Newton is certainly no exception.

Reviews of Books

ATOMIC PHYSICS

By Max Born

Glasgow: Blackie & Son Ltd. Pp. 445 + xiv.
Price 40s. Sixth Edition.

The sixth edition of this classic text-book has been revised by Professor Born with the co-operation of Dr. R. J. Blin-Stoyle. Material has been added to the text at several well chosen points, dealing particularly with the new particles, nuclear forces, accelerators, magnetic resonance and the renormalization procedures for removing divergencies in the theory of fields. There has, however, been

no corresponding addition to the mathematical appendices, which is a pity, for the treatment of each of the last two topics would be much more valuable if an outline of the mathematics of a simple case were given in an appendix.

The wide range of the book is successfully covered by two devices, the rigorous pruning of experimental detail, and the transfer of mathematical proofs which would delay the argument to a series of appendices which occupy a hundred and seventeen pages. For the mathematically inclined student, and the teacher, these contain much of the richest

meat in the book. The main text contains a generally clear and well-ordered exposition both of atomic physics and of a good deal of nuclear physics: the treatment of the physics of solids is relatively less complete and up to date. The style in which workers are cited—by name and year of publication—does not facilitate reference outside the period covered by *Physics Abstracts*, and it cannot be assumed that all undergraduates, even in final year, know how to use the Abstracts, though they certainly should.

The paragraph on van der Waals' forces in the text is rescued from obscurity only by its Appendix. The account of Debye's theory of the specific heat of solids blandly ignores the difference between push and shake waves: while most textbook discussions mislead us in other ways, we know that Professor Born of all people could have given us a clear and correct account. The very useful bibliography misses the much improved new edition of A. H. Wilson's *Theory of Metals*. These imperfections in detail detract little from the value of the book.

For the student of chemistry or engineering, this is not the most suitable text, and even the prospective physicist might preface this book with, for example, Slater's excellent "Modern Physics": but for the honours physics student, and his teachers, it remains one of the best books available. It is also much better value for money than any comparable American book.

G. WYLLIE.

PHYSICAL OPTICS

By R. A. Houstoun

Glasgow: Blackie & Son Ltd. Pp. 300. Price 40s.

The author of the well-known *Treatise on Light* has, in this new book, attempted to condense the subject into a very much smaller space. At the same time he has included some historical matter and a number of new developments which are not to be found in many textbooks, such as phase contrast, schlieren methods, interference filters and recent measurements of the velocity of light. Most of these are explained as well and clearly as the limited space would allow.

In his attempt to cover as wide a field as possible the author has perhaps gone rather too far; the chapters on spectroscopy and quantum theory are too sketchy to be of real value, and a fuller explanation of interference fringes of the Newton- and the Haidinger-type would have been more valuable than the inclusion of such matters as Talbot's bands or Haidinger's brushes.

The attempt at extreme condensation has, perhaps inevitably, led to an undue stress of formulae and their derivation. The concept of wave surfaces and their relation to rays are hardly discussed, and, especially in the chapters on interference, the use of rays in text and drawings is apt to be misleading.

The book is presumably intended for candidates revising for an examination who will, in fact, appreciate its conciseness and wide range. It can be less strongly recommended to those who wish to gain a thorough understanding of the subject.

H. G. KUHN.

DETERMINISM AND INDETERMINISM IN MODERN PHYSICS

By Ernst Cassirer

New Haven: Yale University Press. London: Oxford University Press Ltd. Pp. xxiv + 227. Price 40s.

Owing to the death of the author, this good translation of the 1936 German text does not contain a projected final chapter on developments concerning the causality problem during the last twenty years. Professor Margenau, who had agreed to collaborate in writing this last chapter, contributes an important Preface in which he shows that the depth of Cassirer's analysis was ahead of his time. Since insight in the 1920's provided the foundation for all subsequent discoveries, the book is not out of date. This is evident from the titles of the five parts into which the thirteen chapters are divided.

The historical introduction ranges from Laplace's "hypothetical absolute universal intelligence" to Kant's "critical determinism." The next two parts cover causality in classical physics and causality and probability.

In the fourth part, on the problem of causality in quantum theory, Cassirer urges the necessity for some *fundamentum in re* to provide a secure basis for modern physics. Avoiding the use in a spirit of compromise of the words determinism or indeterminism, he is led to a clear re-statement of an old thesis, namely that every alleged cause that cannot be experienced is fictitious. What is important is his recognition that the ensuing subject-object problem implies an interaction between the problems of physics and of epistemology. This is insufficiently appreciated even to-day.

At one point Cassirer appears to prefer the view that the only goal of physical knowledge is "insight into a strict and precise relation between observable magnitudes" against a substantialist view of the atom. But in the last part, on causality and continuity, he urges the need to change standpoint in moving from one dimension of meaning to another. It may be that a wider survey, including what has been learned in biology and sociology, is needed to elucidate the rules underlying such change of standpoint; could it be that in these rules there would emerge a valid substantialist thesis?

Anyone who wishes to try to understand what we now know from physics will find here much useful material; on finishing the book, he would do well to re-read Professor Margenau's Preface, if only to be convinced of Cassirer's claim that philosophy and physics must mutually invade each other.

R. L. BROWN.

**PROCEEDINGS OF THE THIRD
BERKELEY SYMPOSIUM ON
MATHEMATICAL STATISTICS AND
PROBABILITY. VOL. III.
ASTRONOMY AND PHYSICS**

Edited by J. Neyman

London: Cambridge University Press.

Berkeley: University of California Press.

Pp. 252 + iii. Price 47s.

The three Berkeley symposia, one in 1945/6, the second in 1950 and the third in December, 1954, have had the great value not only of bringing together statistical

problems from very different fields, problems which prove to have a great deal in common, but of providing a survey to date of progress on mathematical statistics. These symposia are not the hurried conferences in which time for discussion has to be stolen from the time for presentation of papers but consist of lectures especially prepared by leading workers in each field delivered, in the case of the theoretical papers, at a session lasting two months. It is understandable therefore that the Proceedings extend to five parts, of which this is the third. Others deal with biology and problems of health and Econometrics, Industrial Research, and Psychometry. Two other volumes, I and II, are devoted to theory.

The papers are of the same high standard as those of previous symposia and provide what are in effect monographs on the subjects of the several titles. In the Physics part of the present volume (102 pp.) there are papers entitled Statistical Mechanics and Probability Theory, Foundations of Kinetic Theory, Random Solutions of partial differential equations, Theory of vibration of simple cube lattices and Non-linear prediction and Dynamics.

Much development of mathematical statistics has taken place outside the field of physics, even of nuclear physics, and it is only of recent years that some of the newer thought has been used in it. The statistical problems involved in a particulate theory of matter were early recognized but the fact that until comparatively recently the physicist could only observe properties of whole systems led to a state in which expected (i.e. average), or alternatively most probable, properties were accepted as the only useful derivations from statistical theory. Even though the study of individual particles has become possible it is still necessary to consider properties of infinitely large groups and these are now seen as the ergodic or stable properties of stochastic processes. An interesting survey of the subject from this point of view by Moyal has appeared, and is referred to in the present volume, in the journal of the Royal Statistical Society (Series B) of 1949.

The boundary conditions of a partial differential equation expressing some physical process may themselves be statistical in the sense that they may be different at different times yet be describable by frequency distribution. The resulting distribution of solutions of the differential equation are similarly related and form a set.

The paper on the theory of vibration of simple lattices considers the random yet related displacements of the atoms or molecules of a crystal lattice. These are obviously of importance in the theory of the electrical properties of crystals, superconductors and semiconductors.

The short paper on non-linear prediction sets out some thoughts on the difficulties of meteorological (and other) prediction which arise because the very localized observations ("sparse in space and sparse in time") cannot very precisely represent the larger area and period they are required to represent. A gust of wind for example is a very local phenomenon.

The inclusion of the papers on Astronomy in the same volume with those on physics is an acknowledgment of the similarity of the problems involved in the study of systems of particles of the two extremes of size. In the case of astronomical bodies the ordinary problems of inference from observation are complicated by the impossibility of choosing a sample completely at random since only a limited number are accessible to our observations.

E. D. VAN REST.

FOUNDATIONS OF NUCLEAR PHYSICS

Edited by R. T. Beyer

London : The Mayflower Publishing Co. Ltd.
New York : Dover Publications Inc. Pp. viii + 272. Price 14s.

This book, which carries the publication date 1949, is in two parts : the first of these consists of facsimiles of thirteen fundamental papers in the field of nuclear physics, the second rather shorter part is a classified bibliography brought up to early 1947.

The first part admirably meets an important requirement. The selection, which

includes two early Rutherford papers, the Gamow paper on α -activity, that of Fermi on β -decay and those of Chadwick on the neutron and Anderson on the positron, covers material which is within the compass of most students and of which every senior undergraduate should read some part in the original. This has become almost impossible in large physics departments if only the normal journal copies are available, for each man cannot have access to the papers he wants to read as he comes to them. The present collection should put most of these papers readily within reach. Whatever minor variations of choice may come to mind, the editor is to be congratulated on his selection. A criticism is that the papers should have been given in chronological sequence and not in the alphabetical order of the authors.

However useful it may have been in 1949, the bibliography which forms the second part of the book is now of no great value. It was surely an error of judgment to combine the first part, which is by its very nature of long-term interest, with so substantial a work of bibliography which, in a rapidly developing subject, cannot possibly have been expected to retain its interest. In spite of this, the value of the collection in the first part is so great that the book as a whole must be most strongly recommended.

J. G. WILSON.

RELAXATION SPECTROMETRY

By E. G. Richardson

Amsterdam : North Holland Publishing Co.
Pp. viii + 140. Price 40s.

This monograph is concerned with the phenomena associated with the passage of mechanical vibrations through matter, or, more specifically, with the measurement and interpretation of those characteristic energy losses which make up what may be called the "relaxation spectrum" of any given material. The spectrum is divided for convenience into the infrasonic, the sonic, and the ultrasonic regions ; for each the appropriate experimental techniques, and results for specific materials are

presented. The selected data refer to a wide variety of materials, including liquids and gases, metals and high polymers.

Although a companion volume by another author, dealing with the relevant theory, is promised, it is to be regretted that Professor Richardson has not provided in the present work a more coherent underlying theme or general theoretical framework for the interpretation of the phenomena reported. The theoretical introduction actually included is so inadequate, and in places inaccurate, that it fails to satisfy this requirement.

The standard of production also leaves something to be desired, there being an unduly large number of typographical and other minor errors.

L. R. G. TRELOAR.

GENERAL SCHOOL PHYSICS— MECHANICS, HYDROSTATICS AND SOUND

By R. Stone and N. Bronner.

London: English Universities Press Ltd. Pp. 363 + ix. Price 9s. 6d.

This is the second volume of the three to be published under the title General School Physics, the series being planned to meet the needs of students taking the Ordinary level paper, and is itself part of a wider series of textbooks intended to form a uniform course of study up to the end of the sixth form course. The editor, the Senior Science Master of Manchester Grammar School, says in his introduction that the emphasis will be on understanding rather than knowing, an idea which carried far enough into our Grammar School teaching would help to solve a number of the problems that beset us.

The treatment of the subject matter is, in the main, experimental and there are many references to present day applications of physical principles and the book is very well illustrated. It does, in fact, admirably fulfil its function, and adverse criticism must be of a minor nature.

The authors, aware of the difficulty of introducing clearly the idea of mass at too

early a stage, have stated the Law of Universal Gravitation and advised the reader in a footnote that he may substitute weight for mass "without too much error." Using the definition of weight, given previously, as the downward attraction of matter to the centre of the earth, this would seem to make a muddle, to a thinking pupil, of the statement of the Law of Gravitation. It would perhaps have been better to have left the statement of the law until mass had been defined.

In this age of record-breaking, the only reason for mentioning records (p. 41) would seem to be to serve the interests of history, but in that case, other than the latest known record should be noted.

Occasionally the style is not precise. For example, on p. 215 we are told that "distance travelled . . . is the whole of the shaded area under the graph," and again on p. 115 the introduction of "represents" would serve the interests of accuracy. Nevertheless, this book is an excellent one and is to be strongly recommended.

KATHLEEN E. PARKS.

MODERN COMPUTING METHODS — NOTES ON APPLIED SCIENCE, No. 16

London: Her Majesty's Stationery Office. Pp. 128 + vi. Price 10s. 6d.

These notes on computation are based on lectures delivered by various members of the staff of the Mathematics Division of the National Physical Laboratory and attended by representatives of industrial firms. Three of the first four chapters deal with the solution of algebraic equations, the inversion of matrices, and the determination of latent roots and vectors. Chapter 3 is concerned with the evaluation of real and complex roots of polynomial equations. In Chapter 5, sundry finite-difference formulae for interpolation, differentiation and integration are introduced and form the basis of the methods of solving differential equations discussed in subsequent chapters. Chapter 6, concerned with two-point boundary value problems, describes one method in which the differential

equation is replaced by a set of finite-difference equations which are then solved by one of the standard methods for simultaneous algebraic equations. The higher-order difference correction is first ignored and then included in subsequent approximations. Other methods are not mentioned. Chapter 7 offers several methods for dealing with initial-value problems, with emphasis on the use of recurrence relations. The account of the use of characteristics in the solution of hyperbolic partial differential equations does much to remove the veil of obscurity which usually surrounds this topic. Chapter 9 describes very briefly methods of handling parabolic and elliptic partial differential equations, and relaxation methods are discussed more fully in Chapter 10. Chapters 11 and 12 give some idea of alternative ways of dealing with the problems which arise when mathematical functions, integrals, series, etc., have to be

evaluated and tabulated. Examples of the use of *Deuce* and of a mechanical differential analyser are given in appendices.

The outstanding attraction of this book is that it contains accounts of methods written by men who know them to work in practice because they have tried them. It is to be commended for its conciseness and for presenting sound practical advice stripped of all distractions and of much of the dead wood of old classical methods. Complete details are not to be expected in so few pages but there is a useful bibliography of much of the important and accessible literature. The book will doubtless form the basis of many teaching courses in the subject. It seems a pity that the contributors remain anonymous. Presumably they were not disguised when they delivered the lectures on which the book is based.

J. CRANK.

News of Members

FELLOWS

W. D. Bennett has recently taken up a post with Canadian Westinghouse Co. Ltd., Ottawa.

N. B. Bhatt is now with the Defence Science Organization, Ministry of Defence, New Delhi.

J. Crank has recently been appointed Head of Mathematics Department, Brunel College of Technology, Acton.

R. Eisenschitz has been appointed to the Chair of Theoretical Physics at Queen Mary College, London.

M. R. Hopkins has been appointed Senior Lecturer in Physics at University College of Swansea.

M. Ishaq has been appointed Head of the Physics Division of the Pakistan Council of Scientific and Industrial Research, Lahore.

A. Quinton is now a Production Controller in the Industrial Group, United Kingdom Atomic Energy Authority, Risley.

J. Reekie is now employed as Chief Engineer at Semiconductors Ltd., Ilford.

J. B. Reed has been appointed Manager of Electronic Data Processing, Trans-Canada Air Lines.

G. L. Rogers has taken up an appointment as Senior Lecturer at the College of Advanced Technology, Birmingham.

ASSOCIATES

J. C. Bell has been promoted to the grade of Principal Scientific Officer in U.K. Atomic Energy Authority, Cumberland.

J. Bennett has taken up a post in the Vacuum and Induction Furnace Division of Wild-Barfield Electric Furnaces Ltd., Watford.

D. E. C. Corbridge has recently taken up an appointment in the Research Department of Unilever Ltd., Port Sunlight.

- T. H. Dennis is now Senior Science Master of Withernsea High School.
- G. Evans is now working at Garnett Training College for Technical Teachers, London.
- S. R. Govindarajan has been appointed Professor of Physics at A. M. Jain College, Madras.
- J. H. Harris has taken up a new post as Lecturer at Barrow Technical College.
- H. G. Jones is now Deputy Head of Laboratories of U.K. Atomic Energy Authority, Dounreay.
- J. W. Kirk has taken up an appointment with Ministry of Supply, Sevenoaks.
- P. Lord is now Senior Lecturer in Physics at the Royal Technical College, Salford.
- M. McChesney has been appointed Research Physicist with the British Thomson Houston Co. Ltd., Rugby.
- P. J. Palmer has taken up a new post with John Thompson Ltd., Wolverhampton.
- F. A. Purdy is now Headmaster of The Secondary Technical School, Barnsley.
- Joan M. Rooke has recently taken up an appointment as Spectrographer in the Research Institute of African Geology, University of Leeds.
- A. M. Short has been appointed Lecturer at College of Technology, Birmingham.
- W. S. Sinclair has taken up a post with John Thompson Nuclear Energy Co. Ltd., Knutsford.
- M. E. Sprinks has been appointed one of Her Majesty's Inspectors of the Ministry of Education.
- H. R. Wilson has been appointed Lecturer in Physics at Queen's College, Dundee.
- GRADUATES**
- D. R. Arnott is now Assistant Mathematics Master at Morrison's Academy for Boys, Creiff.
- J. M. Brander has recently been appointed Professional Officer in the Meteorological Office, Southern Rhodesia.
- Miss B. M. Bell is now Physics Mistress at Blackburn High School for Girls.
- D. J. Cooper has recently been appointed Senior Science Master of Don Valley High School.
- P. J. Coopen has taken up an appointment with the Telecommunications Establishment of the Defence Research Board, Ottawa.
- R. H. A. Davies has taken up an appointment in the Department of Printing and Photographic Technology of the Manchester College of Science and Technology.
- W. R. Eadington has taken up an appointment at South Shields Grammar Technical School for Boys.
- D. R. G. Ford is now an Engineer with The English Electric Co. Guided Weapons Division, Luton.
- I. R. Hardwick has taken up an appointment as Scientist with Vickers Group Research Establishment, Weybridge.
- D. V. Harris has recently been appointed Design Engineer with the Canadian Westinghouse Co. Ltd., Ottawa.
- C. S. Hope is now a Physicist with The Arthur Little Research Institute, Musselburgh.
- J. Kosky has been appointed Research Engineer with Elliott Brothers (London) Ltd., Boreham Wood.
- D. Lackey is now employed as a Physicist in the Technical Department of Thomas De La Rue Ltd., North Shields.
- R. S. Morland has recently taken up an appointment as Assistant Lecturer at Luton Technical College.
- F. Rainford is now Physics Master at Harrogate Grammar School.
- G. W. E. Robertson is now employed as a Control Engineer of Standard Telephones and Cables Ltd., Sidcup.
- D. I. Strike has been appointed Assistant Lecturer at The Technical College of Monmouthshire, Crumlin.
- D. S. Wilde has been appointed Senior Engineer with E.M.I. Electronics Ltd., Wells.

Forthcoming Institute Meetings

- Nov. 19** Scottish Branch In the Department of Natural Philosophy,
University of Glasgow, 7.15 p.m.
"Nuclear Power Production"
MR. D. C. G. SMITH
(United Kingdom Atomic Energy Authority, Dounreay)
- Nov. 20** Yorkshire Branch In the Physics Department, University of Sheffield, 5 p.m.
"The Velocity of Light"
DR. L. ESSEN
(National Physical Laboratory, Teddington)
- Nov. 22** South-Western Branch At the Royal Military College of Science,
Shrivenham, 7 p.m.
"The Field Emission of Electrons"
PROFESSOR F. A. VICK, O.B.E., F.Inst.P.
(University College of North Staffordshire)
- Nov. 27** London and Home Counties Branch
In the lecture theatre of the Royal Institution, 2.30 p.m.
A symposium on
"The Design of Physics Research Laboratories"
Chairman : DR. J. S. FORREST, F.Inst.P.
Speakers will include :
DR. BASIL SPENCE (Basil Spence and Partners)
DR. T. EMMERSON, A.Inst.P. (G.K.N. Group Research Laboratory)
MR. B. S. FLEMING-WILLIAMS (Sylvania-Thorn Colour Television Laboratories)
MR. J. C. CORNWELL (The General Electric Co. Ltd., Research Laboratory)
DR. R. G. HOPKINSON (Building Research Station)
MR. D. A. OLIVER, F.Inst.P. (B.S.A. Group Research Centre)
(Admission is **by ticket only**, obtainable from the Institute)
- Dec. 4** Midland Branch 2.30 p.m.
Visit to Triplex Safety Glass, King's Norton
followed by
"Modern Safety Glass"
DR. A. J. HOLLAND
(Triplex Safety Glass Ltd.)
- Dec. 4** North-Eastern Branch At King's College, Newcastle-upon-Tyne, 6.15 p.m.
Tea 5.30 p.m.
"The Physics of Fibres"
DR. A. B. D. CASSIE, F.Inst.P.
(Woollen Industries Research Association)
- Dec. 4** Education Group At the Institute's House, 6 p.m.
"Physics and Aesthetics"
MR. F. I. G. RAWLINS, F.Inst.P.
(The National Gallery)

- Dec. 6** Liverpool and North Wales Branch
In the Department of Electrical Engineering, University of Liverpool, 7 p.m.
Tea 6.30 p.m.
"Cerenkov Radiation"
DR. J. V. JELLEY
(Atomic Energy Research Establishment, Harwell)
- Dec. 6** South Wales Branch In Physics Department, University College of
South Wales and Monmouthshire, Cardiff, 5.15 p.m.
Branch Annual General Meeting
followed by
"Microwave Triodes"
PROFESSOR M. R. GAVIN, F.Inst.P.
(University College of North Wales, Bangor)
- Dec. 6** Non-Destructive Testing Group At the Institute's House, 6 p.m.
Tea 5.30 p.m.
"Structural Imperfections in Metals and their effect on Mechanical Properties"
PROFESSOR N. F. MOTT, F.Inst.P., F.R.S.
(University of Cambridge)
- Dec. 10** Electronics Group At the Institute's House, 5.30 p.m.
Tea 5 p.m.
"Infra-red and microwave modulators using free carriers in Germanium"
DR. A. F. GIBSON
(Royal Radar Establishment, Great Malvern)
- Dec. 11** London and Home Counties Branch At the Institute's House, 6 p.m.
Tea 5.30 p.m.
"Irregularities and Movements in the Ionosphere"
DR. B. H. BRIGGS
(University of Cambridge)
- Dec. 11** Scottish Branch At the Royal Philosophical Society of Glasgow,
207 Bath Street, Glasgow, 7 p.m.
Joint lecture with Royal Philosophical Society of Glasgow
"Lord Kelvin"
PROFESSOR P. I. DEE, C.B.E., F.R.S.
(University of Glasgow)

Physical Society Meetings

Members of the Institute are invited to attend the following meetings of the Physical Society :

- Nov. 26** Low Temperature Group
 Joint Meeting with the Institution of Chemical Engineers
 on
"Recent Developments in Industrial Gas Separation"

Nov. 28

"Alignment Devices"
MR. J. DYSON and DR. J. M. BURCH
"Stereoscopic Pointing"
MR. PALMER

Optical Group

Dec. 11

"Report on the Paris Meeting on Colour Television, 1957"
MR. L. C. JESTY
"Report on the Meeting of the CIE Working Party on Calorimetry, Teddington, 1957"
PROFESSOR W. D. WRIGHT
"Report on the Symposium on Visual Problems of Colour Teddington, 1957"
DR. W. S. STILES

Colour Group

At Imperial College, London, 3.30 p.m.

Dec. 19-20

Two-day Conference on
"Band Theory of Metals and the Structure of the Fermi Surface"
At Imperial College, London
(A conference fee of one guinea is payable)

Low Temperature Group

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON OCTOBER 1, 1957

An asterisk () indicates transfer from another grade*

FELLOWS

- Beurle, Raymond Louis, B.Sc., Ph.D., Lecturer, Imperial College, London.
Farago, Peter Stephen, Ph.D., Senior Lecturer, University of Edinburgh.
Frank, Frederick Charles, B.A., B.Sc., D.Phil., F.R.S., Professor of Physics, University of Bristol.
*Giovannelli, Ronald Gordon, D.Sc., Senior Principal Research Officer, C.S.I.R.O., Australia.
Holland, Leslie, Head of Vacuum Coating Research Laboratory, Edwards High Vacuum Ltd., Crawley.
Ingram, David John Edward, B.A., D.Phil., Reader in Electronics, University of Southampton.
*Wolfindale, Arnold Whittaker, B.Sc., Ph.D., Lecturer, University of Durham.

ASSOCIATES

- *Balashov, Vladimир, Ph.D., Physicist, Mines Department, Northern Rhodesia.

- *Barrow, Colin Home, M.A., B.Sc., Instructor in Physics, University of Florida.
Bawdekar, Vaman Shantaram, M.A., M.Sc., Valve Development Engineer, The Edison Swan Electric Co. Ltd., Brimsdown, Middlesex.
Clark, Cyril Egerton, B.Sc., Assistant Lecturer, College of Technology, Bristol.
*Davies, Stanley, B.Sc., Research Physicist, Monsanto Chemicals Ltd., Newport, Mon.
Dorgan, William Leonard, M.A., M.Sc., Senior Lecturer, Technical College, Bolton.
*Dunster, Dave Francis Thomas, B.Sc., Senior Physicist, Standard Telephones & Cables Ltd., Harlow, Essex.
Firth, Kenneth, B.Sc., Ph.D., Research Physicist, A.E.I. Research Laboratory, Aldermaston, Berkshire.
*Freemantle, Reuben George, B.Sc., Ph.D., Scientific Officer, U.K. Atomic Energy Authority, Harwell, Berkshire.

- Godfrey, Eric Gordon, B.Sc., Lecturer, Borough Polytechnic, London.
- Hopper, Denys Sydney, B.Sc., A.R.C.S., Section Leader, The General Electric Co., Ltd. of England, Salisbury, South Australia.
- *Hyde, Geoffrey Robert, B.Sc., Research Officer, Wiggins Teape Group Research Organization, Beaconsfield, Bucks.
- John, Ieuan Gwynydd, B.Sc., Director, Meteorological Service, Malaya.
- Johnson, Frank Alan, M.Sc., Ph.D., Scientific Officer, U.K. Atomic Energy Authority, Harwell, Berkshire.
- Lewis, Brian, B.Sc., Ph.D., Scientific Staff, The General Electric Co. Ltd., Wembley, Middlesex.
- Lewis, Joan, B.Sc., Assistant Lecturer, Aston Technical College, Birmingham.
- Loneragan, John Patrick, M.Sc., Senior Scientific Officer, Weapons Research Establishment, Salisbury, South Australia.
- *Marr, Geoffrey Richard, M.Sc., Lecturer, North Herts Technical College, Letchworth.
- Massalski, Tadeusz Bronislaw, B.Sc., Ph.D., Lecturer, University of Birmingham.
- *Masterman, John Raymond, B.Sc., Head of Science Department, Deacon's School, Peterborough.
- May, William Donald, B.Sc., Technical Officer, I.C.I. Paints Division, Slough, Bucks.
- Morant, Martin John, B.Sc., Ph.D., Physicist, The General Electric Co. Ltd., Wembley, Middlesex.
- Newcombe, Raymond John, M.Sc., Lecturer, College of Technology, Liverpool.
- *Nichols, Kenneth Graham, B.Sc., Senior Lecturer, North Herts. Technical College, Letchworth.
- *Osborne, Denis Gordon, B.Sc., Ph.D., Lecturer, Fourah Bay College, Sierra Leone, Africa.
- Paige, Wyndham Somerville, B.Sc., Head of Statistics Section, Imperial Tobacco Co. Ltd., Bristol.
- Reeves, Paul Anthony Thomas, B.Sc., Naval Application Officer, H.M. Underwater Detection Establishment, Portland.
- Richards, Gordon Stanley, B.Sc., Physicist, Standard Telephones & Cables Ltd., Paignton, Devon.
- Richards, John Morgan, B.Sc., Development Engineer, S. Smith & Sons (England) Ltd., Cheltenham, Glos.
- *Richmond, Margaret Ann, M.A., B.Sc., Head of Physics Department, High School for Girls, Horsham, Sussex.
- Roberts, Joseph Patrick, B.A., B.Sc., Lecturer, University of Leeds.
- *Robertson, Gavin William Edward, M.Sc., Physicist, North Thames Gas Board
- Robinson, Laurence Charles, B.Sc., Scientific Officer, Department of Supply, South Australia.
- *Rolls, Ian Frank, B.Sc., Head of Science Department, L.C.C. Comprehensive School, Tulse Hill, London.
- *Sarkar, Ananta Bikram, M.Sc., Physicist, Electro Acoustic Industries Ltd., London.
- *Shuttlewood, George Douglas, B.Sc., Senior Scientific Officer, Ministry of Supply, London.
- Spurgin, Charles Bernard, M.A., Senior Science Master, Wolverhampton Grammar School.
- Thomas, David Kenneth, B.Sc., Senior Lecturer, Royal Military College of Science, Shrivenham, Wilts.
- *Whigham, Jack Williamson, B.Sc., Physicist, Elliott Bros. Ltd., Borehamwood, Herts.
- Williamson, John Brian Peter, M.A., Ph.D., Research Scientist, Tube Investments Ltd., Hinxton Hall, Cambridge.
- *Young, Ronald, B.Sc., Research Physicist, The Trinidad Oil Co. Ltd., Trinidad.

GRADUATES

- *Aldrick, Anthony William, B.A., Physics Master, Thornbury Grammar School, Glos.
- *Arnold, Kenneth Wiltshire, B.A., Research Student, Clarendon Laboratory, Oxford, low, Bucks.
- Bamford, Keith, B.Sc., Assistant Physics Master, Wheelwright Grammar School, Dewsbury.
- *Blake, Christopher, B.A., Engineer, British Telecommunications Research Ltd., Taplow, Bucks.

- Braden, Michael, B.Sc., Technologist, British Rubber Producers Research Association, Welwyn Garden City, Herts.
- Brady, Kenneth John Dudley, B.Sc., Physicist, North Thames Gas Board.
- Bright, Derek, B.Sc., Assistant, Physics Laboratory, Henry Simon Ltd., Cheadle Heath, Cheshire.
- Brooks, Donald Terence, B.Sc., Student, University of Bristol.
- Brown, Alexander Campbell, B.Sc., Physicist, The English Electric Co. Ltd., Stafford.
- Butler, John Reginald, B.Sc., Controls Laboratory, Guided Weapons Department, Bristol Aircraft Ltd.
- *Davies, Peter Gwyn, B.Sc., Research Student, University College of Swansea.
- Denham, Alan Bruce, Experimental Officer, Armament Research and Development Establishment, Woolwich.
- Denton, Michael James, B.Sc., Junior Engineer, De Havilland Propellers Ltd., Hatfield, Herts.
- Dunn, John William, B.A., Research Student, University of Bristol.
- *France, John, Assistant Experimental Officer, U.K. Atomic Energy Authority, Capenhurst.
- Franklin, Allan Gordon, B.Sc., Postgraduate Student, University of Sheffield.
- *Fursey, Roy Albert Evan, B.Sc. Engineer, British Telecommunications Research Ltd., Taplow, Bucks.
- Gaiger, Calvin Max, B.Sc., Technical Engineer, Bristol Aircraft Ltd., Bristol.
- Gates, Maurice Smith, Assistant Experimental Officer, Ministry of Supply.
- Gorman, Geoffrey Patrick, B.Sc., Head of Physics Department, Woodberry Down Comprehensive School, London.
- Hannaford, James, B.Sc., Assistant Experimental Officer, U.K. Atomic Energy Authority, Capenhurst.
- Henderson, John, B.Sc., Experimental Officer, Mechanical Engineering Research Establishment, Glasgow.
- Hillier, Peter Richard, Assistant Experimental Officer, Atomic Weapons Research Establishment, Aldermaston, Berkshire.
- Hunkin, Thomas Barry, B.Sc., Junior Engineer, De Havilland Propellers Ltd., Hatfield, Herts.
- *Ives, Michael Brian, B.Sc., Research Student, H. H. Wills, Physical Laboratory, Bristol.
- Johnstone, Donald Revington, B.Sc., Assistant Physicist, R. H. Harry Stranger, Elstree, Herts.
- Jones, David Kenton, B.Sc., Lecturer-Demonstrator, B.B.C. Engineering Training School.
- *Lewis, Donald Charles George, Experimental Officer, Armament Research and Development Establishment, Fort Halstead, Kent.
- Maitland, Arthur, B.Sc., Physicist, Metropolitan-Vickers Electrical Co. Ltd., Manchester.
- Matthews, Ian McPherson, B.Sc., Science Teacher, Midlothian Education Committee.
- Moore, John Carlton, B.Sc., Development Engineer, Hymatic Engineering Co. Ltd., Redditch, Wores.
- Murgatroyd, Robert Arnold, B.Sc., Assistant Experimental Officer, U.K. Atomic Energy Authority, Risley, Lancs.
- *Myatt, John, B.A., Research Student, University College of North Staffordshire.
- *Oliver, Christopher Brookes, B.A., Physicist, The English Electric Co. Ltd., Stafford.
- Ollet, Robert Leon, Experimental Officer, U.K. Atomic Energy Authority, Harwell, Berkshire.
- Owen, Denis Brian Bernard, B.Sc., Physicist, The English Electric Co. Ltd., Stafford.
- *Payne, Robert, Senior Technical Assistant, Dunlop Research Centre, Erdington.
- Petley, Brian William, B.Sc., Research Student, Imperial College, London.
- Rees, Euros Powell, B.Sc., Head of Physics Department, Amman Valley Grammar School, Wales.
- *Robins, John Linton, B.Sc. Research Student, University of Western Australia.
- Ryder, Edward Alexander, B.Sc., Scientific Staff, The General Electric Co. Ltd., Stanmore, Middlesex.
- Sansom, David John, B.Sc., Research Student, University of Nottingham.

- Sansom, Harry Charles, Assistant Experimental Officer, U.K. Atomic Energy Authority, Harwell, Berkshire.
- *Spence, John Begg, Physicist, Royal Beatson Memorial Hospital, Glasgow.
- *Stratford, Peter James, B.Sc., Research Student, College of Science and Technology, Manchester.
- Storr, Thomas Henry, Experimental Officer, Atomic Weapons Research Establishment, Aldermaston, Berkshire.
- *Suhr, Robert Walter, B.Sc., Research Physicist, The English Electric Co. Ltd., Whetstone, Leics.
- Thomas, Lewis Frederick Webster, Experimental Officer, Ministry of Supply, Kent.
- *Thomson, James Stewart, B.Sc., Research Student, University of Glasgow.
- Thorne, Leslie William, B.Sc., Senior Physics Master, Drayton Manor Grammar School, London.

- Warren, Robert Francis, B.Sc., Assistant Experimental Officer, U.K. Atomic Energy Authority, Capenhurst.
- Warrilow, Kenneth Desmond, Technical Assistant, Associated Electrical Industries Ltd., Aldermaston, Berkshire.
- Welland, John Michael, Technical Assistant, Associated Electrical Industries Ltd., Aldermaston, Berkshire.
- Weller, Alan Frederick, B.Sc., Technical Officer, British Nylon Spinners Ltd., Pontypool, Mon.
- Werblow, Warren, B.Sc., Scientist, National Coal Board, Isleworth.
- Younger, Alexander Seers, Trials Co-ordination Officer, Royal Aircraft Establishment, Aberporth.

30 students and 2 subscribers were also elected.

The Institute's Journals

PRINCIPAL CONTENTS OF THE NOVEMBER, 1957, ISSUES

Journal of Scientific Instruments: Volume 34, No. 11

CONFERENCE REPORT

Instruments for use in occupational hygiene.

By C. N. Davies, F.Inst.P. (*London School of Hygiene and Tropical Medicine, Keppel Street, London*).

Eight papers were read at the Conference reported in this article. The subject matter included the planning of sampling programmes for maintaining a healthy working environment in industry and the assessment of incompletely defined atmospheric pollution from observations on human subjects. Instrumentation for safety in mining was described with special reference to gas and dust explosions, pneumoconiosis and non-destructive testing. Details were given of the technical precautions needed when taking chest X-rays for the clinical assessment of pneumoconiosis.

The assessment of samples of toxic vapours, secured with a simple hand pump, was covered in a paper

which surveyed recent improvements in absorption methods; the more complex apparatus required for absorption spectrophotometry over a wide range of wavelengths was also reviewed. Safety in the presence of atomic radiations was considered in two papers, one dealing with instruments for measuring and monitoring radiation and the other with instruments used to aid clinical diagnosis of the consequences of human exposure.

ORIGINAL CONTRIBUTIONS

A high-precision photoelectric polarimeter.

By E. J. Gillham (*Light Division, National Physical Laboratory, Teddington, Middlesex*).

In this instrument, which has been designed primarily for standardization work on quartz control plates, the half-shade principle familiar in visual polarimeters is realized, in a slightly different form, by means of a

revolving disk carrying segments of optically-active quartz. These cause the plane of polarization of the light incident on the analyser to alternate between two positions at a low audio-frequency; the setting position of the analyser is that in which the intensity of the emergent light, as indicated by means of a photomultiplier and a.c. amplifier, is unmodulated. The precision of setting is about ten times better than that of a visual instrument. For measuring specimens of small optical activity, use is made of the Faraday effect to balance out the rotation produced by the specimen, thus obviating the need for angular scale readings.

Some improvements in the operation of the optical diffractometer. By C. A. Taylor, F.Inst.P., and B. J. Thompson (*College of Science and Technology, Manchester, I.*).

A systematic method of adjusting the components to bring their optical axes into coincidence is described. This is followed by an account of a theoretical study of the variation of partial coherence which leads to the formulation of a set of practical rules for choosing the correct size of pinhole for a particular problem. Some minor improvements in the design of the diffractometer and in the photographic techniques employed are also described.

A low-frequency random signal generator. By J. C. West (*Electrical Engineering Department, University of Manchester*) and G. T. Roberts (*Bruce Peebles and Co. Ltd., Edinburgh*).

Conventional random signal sources such as photomultipliers, gas discharge tubes, etc., although good at medium and high frequencies are unreliable at frequencies below about 50 c/s. due to flicker effect. The paper describes a simple method of generating a low frequency random signal having a spectrum extending down to zero frequency, and using a gas discharge tube as the primary noise source. The gas discharge tube has been chosen because of the relatively large noise power available, for instance, this may be 10 V r.m.s. in the band spectrum up to 10⁷ c/s. The probability distribution of the resulting signal approaches a Gaussian form. The difference from a

true Gaussian is very small and may be neglected in most experimental work.

The time behaviour of logarithmic amplifier input circuits. By T. P. Flanagan, A.Inst.P. (*British Scientific Instrument Research Association, Chislehurst, Kent.*)

The non-linear nature of the logarithmic amplifier input circuit causes the time constant to vary with current, and three definitions of effective time constant are examined, based on an analysis of the time behaviour of the input circuit to a step change of input current.

Some further results on the rubber membrane theory and Laplace's equation. By W. Fulop, A.Inst.P. (*Standard Telecommunication Laboratories Ltd., Enfield, Middx.*)

Some further results and points are presented to underline the theory of constant horizontal tension of the rubber membrane as discussed in a previous paper by the author.⁽¹⁾ Small deflexion theory which assumes constant resultant tension fails, in the case of coaxial geometry, to account at large deflexions for (a) the linear force-deflexion law obtained and (b) the close correspondence of the membrane's contour to Laplace's equation. Both observations are successfully predicted by the revised theory which places no limitations on geometry or deflexion for the above two conditions to hold. Experiment also confirmed a linear force-deflexion law for an asymmetric geometry.

Fizeau-type interference between beams of light reflected from three surfaces. By A. H. Cook (*National Physical Laboratory, Teddington, Middlesex*).

Optical interference phenomena between beams of light reflected from three surfaces are described and analysed. The distinctive feature of the fringe system is that the field is crossed by bands of intensity equal to that of light reflected from one of the surfaces, delineating the lines of constant separation of the other two surfaces. The use of the phenomena in metrology is briefly discussed.

British Journal of Applied Physics: Volume 8, No. 11

SPECIAL ARTICLES

Summarized proceedings of a conference on X-ray analysis—Cardiff, April, 1957.

The Spring Conference of the X-ray Analysis Group of The Institute of Physics was held in the Physics Department of University College, Cardiff, on 5 and 6 April, 1957. The topics under discussion were the structures of minerals and inorganic compounds.

Summarized proceedings of a meeting on low temperature distillation—London, March, 1957.

An all-day discussion meeting on low temperature distillation was held by the Low Temperature Group of The Physical Society at The Institute of Physics, London, on Friday, 22 March, 1957.

Summaries of the papers that were read and discussed are given in this report.

ORIGINAL CONTRIBUTIONS

Viscous flow between rotating cylinders and a sheet moving between them. By M. R. Hopkins, F.Inst.P. (*Department of Physics, University College of Swansea*).

The motion of a sheet, emerging from a liquid and passing between a pair of cylindrical rollers, is considered. An expression for the thickness of the liquid layer finally left on the sheet is derived in terms of the viscosity of the liquid, the size of the rollers, the speed at which the sheet moves through them and the force with which they are pressed together.

Arc motion with magnetized electrodes. By A. E. Guile, T. J. Lewis, and S. F. Mehta (*Department of Electrical Engineering, Queen Mary College, London*).

The velocities of d.c. arcs moving in air at atmospheric pressure between horizontal and parallel cylindrical electrodes have been measured. The arcs moved freely in straight regular tracks in an axial direction under the action of magnetic fields set up by the current flow in the electrodes. Ferrous and non-ferrous electrodes were used and it was found that the axial velocity increased with the current in all cases, but was very much greater in magnitude for the steel electrodes. The hypothesis that the magnetic properties of the steels were responsible for the higher velocities was tested by magnetizing these materials in the axial direction along the electrodes. The cathode and anode spots then described helical paths with the anode moving in an opposite sense to the cathode, the circumferential component of the velocity being provided by the axial flux. It was deduced that magnetic fields within the electrode surfaces determined the motion.

It is suggested that transverse galvanomagnetic and thermomagnetic forces modify the electron emission and are responsible for the cathode motion. It appears that these forces also influence the motion of the anode spot.

A simple calibration technique for improving the accuracy of a Smith resistance thermometry bridge. By G. C. Lowenthal,

A.Inst.P. (*Defence Standards Laboratories, Department of Supply, Melbourne, Australia*).

The Smith resistance thermometry bridge (type 3) used at Defence Standards Laboratories is subject to irregular drifts which cause errors exceeding $\pm 0.002^\circ\text{C}$ between 0 and 100°C and $\pm 0.01^\circ\text{C}$ at 630°C . These errors cannot be dealt with successfully by potentiometric calibrations. An analysis shows, however, that provided certain conditions are satisfied, an external decade of stable 10Ω resistors can be used to reduce the errors to ± 0.0005 and $\pm 0.001^\circ\text{C}$ respectively, since the calibration is sufficiently simple and quick to be repeated as often as required.

The damping effect of surrounding gases on a cylinder in longitudinal oscillation. By M. T. Browne and J. R. Pattison, A.Inst.P. (*Department of Physics, Imperial College of Science and Technology, London*).

The external damping influences on a longitudinally vibrating cylindrical bar are examined quantitatively. Experiments undertaken to confirm the theoretical estimations indicate a possible precision method for the determination of gas viscosities.

On the ultimate concentration distribution in zone-melting. By I. Braun (*Hebrew Institute of Technology, Dept. of Physics, Haifa, Israel*).

This paper treats the question of the ultimate concentration distribution, that is the distribution which is unaffected by further passes. An exact solution is given of this ultimate distribution for any value of the distribution coefficient k , taking into account the end-effect due to the normal freezing in the last zone. Graphs of the ultimate distribution are given for different values of k and the zone-length. To know how many passes are needed to reach the ultimate distribution, these graphs have been compared with the graphs of the successive concentration profiles. After a certain number of passes the concentration profiles oscillate around the ultimate distribution. These oscillations become smaller and smaller with increasing number of passes. There exists therefore an optimum number of passes with the lowest concentration profile.

COMMONWEALTH OF AUSTRALIA
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL
RESEARCH ORGANIZATION

DIVISION OF ELECTROTECHNOLOGY

Appointment No. 760/88 of Research Officer

Applications are invited for appointment to a position of Research Officer with the Organization's Division of Electrotechnology, located at the National Standards Laboratory, in the grounds of the University of Sydney, New South Wales.

The appointee will be required to undertake research and to develop techniques and equipment for establishing standards of electrical measurements at high frequencies.

Initially the work will be concerned with the measurement of impedance and power in co-axial lines at frequencies up to 3,000 mc/s.

Applicants should possess at least a University Honours degree in Science with Physics or Mathematics as a major subject, or in Physical Engineering or equivalent qualifications together with appropriate research experience. Experience in electronic techniques is desirable.

Commencing salary is dependent upon the appointee's qualifications and experience, and will be determined within the salary range of Research Officer £A1,313-£A1,938 p.a.

In the case of an appointee domiciled overseas, first class sea fares to Australia will be paid for the appointee, his wife and family.

The appointment will be conditional upon a satisfactory medical examination, and the appointee will be required to contribute to and eligible to receive benefits from either the Commonwealth Superannuation Fund or the Commonwealth Provident Account.

Applications quoting Appointment No. 760/88, and stating full name, place, date, and year of birth, nationality, marital state, present employment, particulars of qualifications and experience, and of war service, if any, accompanied by copies of not more than four testimonials and the names and addresses of three referees acquainted with you professionally, should reach the undersigned, from whom further particulars may be obtained by December 21, 1957.

(A. Shavitsky)

Chief Scientific Liaison Officer.

Australian Scientific Liaison Office,
Africa House,
Kingsway,
London, W.C.2.

UNIVERSITY COLLEGE OF NORTH WALES
BANGOR

Applications are invited from physicists or electrical engineers for the post of Lecturer in the Department of Electronic Engineering. Candidates must have had research experience in some branch of valve, transistor or circuit electronics, or in solid state physics. Teaching experience, although desirable, is not essential.

The salary will be on the lecturer scale, with a maximum of £1,650 p.a., together with a family allowance of £50 per child and F.S.S.U. benefits. A salary at or near the maximum will be offered to a candidate with suitable qualifications. The date of appointment will be arranged with the successful candidate.

Two copies of the application should reach the undersigned, from whom further particulars may be obtained, not later than December 15, 1957.

Kenneth Lawrence,
Secretary and Registrar

Physics in Industry Series

PHYSICS OF FIBRES

AN INTRODUCTORY SURVEY

BY

H. J. Woods, M.A., F.Inst.P.

Lecturer in Textile Physics,
University of Leeds

The emphasis throughout this book is on the natural rather than the man-made fibres, but anyone who knows something about cellulose and keratin will find little difficulty with other fibres. The author's object has been to provide an introduction to the subject for scientists commencing research and development work in this field by indicating the lines along which the physical approach to the study of the structure and properties of fibres has proceeded.

He has also had in mind the scientists whose interests are in other fields, but who may wish to learn something about the ways in which physics has helped in advancing our knowledge of fibres.

A bibliography and fairly full list of references have been provided for those who wish to pursue the subject further.

price 30s. including postage,
to members of the Institute 25s.

Several attractive and Senior Positions are offered in the Development and Industrial application of modern non-destructive testing techniques. The positions will be in the following fields:

- (1) Electronic Circuit Development
- (2) Properties of Materials
- (3) Physical Investigation and Measurement

They offer good scope to men of initiative and experience in the above fields. Salaries will be commensurate with the candidate's qualifications and experience.

Applications should be made in writing in the first instance, giving full details of qualifications, previous experience, age and salary required to: Personnel Manager, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex.

SMITHS AIRCRAFT INSTRUMENTS LTD., has an interesting vacancy for a Physicist or Engineer in their Materials Research Branch to develop insulating systems for use in light electrical engineering applications. Candidates should be of degree standard, and preferably acquainted with modern methods of impregnation and encapsulation. A high salary will be payable to right man. Applications, which will be treated in strict confidence, should be addressed to The Personnel Manager, Bishops Cleeve, Cheltenham.

UNIVERSITY OF HONG KONG

Applications are invited for the post of Lecturer in Physics. Annual salary (superannuable) is £1,575 × £50-£2,175 (man) or £1,200 × £40-£1,680 (woman) together with an expatriation allowance of £225 a year if applicable. The equivalent of income tax in the Colony is comparatively low.

First class sea passages are provided for expatriate staff and their families on first appointment and leaves. Applicants should be graduates of a British University or have equivalent qualifications and experience.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of application, in London and Hong Kong, is December 14, 1957.

FERODO LTD., Chapel-en-le-Frith, require the services of a Research Assistant to investigate problems of railway braking, both in the laboratory and in the field. Applicants should have H.N.C. in Physics or Engineering, or an equivalent, and have satisfied National Service commitments. Some knowledge of railway practice would be an advantage. Write, giving full particulars and stating ref. No. 5033, to the Personnel Manager, Ferodo Ltd., Chapel-en-le-Frith, Via Stockport.

THE RESEARCH AND DEVELOPMENT DIVISION OF PETFORDS LTD. require the services of a qualified chemist or physicist to undertake laboratory investigations mainly of a physical nature. Some experience of rheological or taste panel work in the food industry would be an added qualification, but is not essential. A starting salary of not less than £1,000 per year will be paid and the Company operates a plan covering non-contributory pension, sickness benefit and life assurance. Assistance will be given with housing. Applications giving details of education and career to date should be sent to the Chief Personnel Officer, Petfords Ltd., Melton Mowbray, Leicester.

UNIVERSITY OF CAPE TOWN

SOUTH AFRICA

Applications are invited for the Chair of Theoretical Physics in the Department of Physics.

The salary scale is £1,600 × £100-£2,000 per annum. There is also a temporary cost of living allowance for a married man (at present £234 per annum).

Applications (with copies of testimonials) should state age, qualifications, experience and research work completed or in progress and give the names of two referees whom the University may consult.

Two copies of the application and testimonials should reach the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (from whom memoranda giving the general conditions of appointment and further information about the work of the department of physics should be obtained) not later than January 31, 1958. An additional copy should be sent direct by air mail to the Registrar, University of Cape Town; Private Bag, Rondebosch, Cape Town, South Africa, by the same date.

The University reserves the right to appoint a person other than one of the applicants or to make no appointment.

COURSES

MIDDLESEX COUNTY COUNCIL EDUCATION COMMITTEE

BRUNEL COLLEGE OF TECHNOLOGY,
WOODLANDS AVENUE, ACTON, W.3.

A course in Basic Electronics extending over about 25 weeks will be held on Tuesday evenings from 6.30 to 9.30 p.m., commencing November 12, 1957. Fee £2.

Further particulars may be obtained from the Principal.

C. E. GURR, M.Sc., Ph.D.

Secretary to the Education Committee.

MIDDLESEX COUNTY COUNCIL EDUCATION COMMITTEE

BRUNEL COLLEGE OF TECHNOLOGY,
WOODLANDS AVENUE, ACTON, W.3.
(TEL : ACORN 6661)

Principal : J. Topping, M.Sc., Ph.D., D.I.C., F.Inst.P.

MATHEMATICS FOR INDUSTRY

A four year Sandwich Course for the Diploma in Technology in Mathematics will commence in January, 1958. Practical techniques useful for students intending to make a career in industry form a vital part of the course. Details may be obtained from the Head of the Mathematics Department to whom early application should be made.

C. E. GURR, M.Sc., Ph.D.,

Secretary to the Education Committee.

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7 Stone Buildings,
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Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

BRITISH PETROLEUM CO. LTD., have a vacancy in their Exploration Research Laboratories, Sunbury-on-Thames, for a Physicist with an honours degree and several years' research experience, to work on some aspects of elastic wave propagation in the earth. Previous experience of one or more of the following types of work is desirable:

- Instrumental development work on magnetic-tap recording and play-back systems, and particularly the application of correlation and other techniques to the output of multi-channel play-back equipment.
- Design and interpretation of small-scale seismic field programmes.
- Theoretical work on seismic propagation problems. Salary according to age, qualifications and experience. Non-contributory Pension Fund. Assisted house purchase scheme. Removal expenses and settling-in allowance payable in certain cases. Luncheon Club. Write, giving full details, quoting H.3597B, to The Manager, Recruitment Branch, The British Petroleum Co. Ltd., Britannic House, Finsbury Circus, E.C.2.

D.S.I.R. requires staff at Chemical Research Laboratory, Teddington, and Isotope Application Research Group, Harwell. At Harwell (a) Scientific Officer or Senior Scientific Officer Physicist for work on application of radioisotopes. Should have knowledge of radiation measurement problems. (Ref. A322/7A) (b) Experimental Officer to assist in research on radioisotopes. Experience in nuclear radiation measurement or in radiochemistry essential. (Ref. A323/7A). At Teddington, Assistant Experimental Officers for work on methods of concentration and analysis of radioactive ores. Experience desirable in inorganic and physical chemistry. (Ref. F502/7A). Qualifications: Scientific Officer Class: 1st or 2nd class honours degree or equivalent. Experimental Officer Class: G.C.E. advanced level in two Science or Mathematics subjects; over age 22, Pass degree, H.N.C. or equivalent generally expected. Salary ranges (men): (Harwell) S.S.O. £1,130-£1,330. S.O. £595-£1,090. E.O. £920-£1,130. (Teddington) A.E.O. £385 (age 18)-£685 (age 26)-£850. Women's ranges slightly less but equal pay scheme. Five day week. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting appropriate reference.

MATHEMATICAL PHYSICIST or **MATHEMATICIAN** required to join a research team engaged in studying Point Defects in Metals with special reference to radiation damage. Previous experience in this field unnecessary, but candidates must be capable of carrying out independent research without supervision. Appointment for three years at a salary up to £700 p.a. according to qualifications and experience. Applications to Professor J. G. Ball, Metallurgy Department, Imperial College, South Kensington, S.W.7.

HAMMERSMITH HOSPITAL AND POSTGRADUATE MEDICAL SCHOOL DU CANE ROAD, LONDON, W.12.

Applications invited for the newly created post of Director of Physics Department. The person appointed to this post will be in charge of the existing Hospital Physics Department with which are associated the physicists employed by the Postgraduate Medical School and the Institute of Obstetrics and Gynaecology. If a Chair in Medical Physics is created in the Postgraduate Medical School it is hoped that the appointee would be eligible.

A recognized leader outside the sphere of hospital physics would be considered for this post. Minimum salary scale (based on the new award for top-grade physicists) £1,950 × £75 (2) × £100 (2) - £2,500, plus London allowance. An addition at all points of the scale would, however, be offered to a physicist of outstanding ability.

In addition an honorarium for teaching will be paid by the Postgraduate Medical School. Further details of this appointment can be obtained on application. Application stating age and giving full details of previous career (with publications) together with the names of three referees, should reach the Secretary, The Board of Governors, The Hammersmith, West London and St. Mark's Hospitals, Du Cane Road, London, W.12, by January 6.

UNIVERSITY OF HONG KONG

Applications are invited for the post of Assistant Lecturer in Physics. Annual salary (superannuable) is £1,375 × £50-£1,525 (man) or £1,040 × £40-£1,160 (woman) together with an expatriation allowance of £225 a year if applicable. The equivalent of income tax in the colony is comparatively low.

First-class sea passages are provided for expatriate staff and their families on first appointment and leaves. Applicants should be graduates of a British University or have equivalent qualifications and experience.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in Hong Kong and London, is December 31, 1957.

EXPERIMENTALISTS

required at

A.E.R.E. HARWELL

in an Engineering Laboratory, designing and operating test-rigs covering instrumentation; heat transfer and fluid mechanics; physical property measurements; handling of unusual fluids.

G.C.E. "A"; H.N.C.; or degree required.

Salary £990-£1,215 or £395 (at 18)-£885.

Housing; superannuation; excellent conditions. Send postcard for details to Recruitment Officer (9602/110). A.E.R.E., Harwell, Didcot, Berks.



General Chemicals Division
has vacancies for
PHYSICS GRADUATES

These vacancies exist in its

Research Department, Widnes, Lancs., where the posts should be of particular interest to Physicists anxious to apply their theoretical knowledge and experimental ability to the varied scientific problems of industry.

Research in progress includes ultrasonics, mass spectrometry, absorption spectrometry in its many aspects, instrument development, and other fields of fundamental and applied physics.

There are also vacancies in the Division's **Instrument Engineering Department**, Runcorn, Cheshire, where particular attention is being paid to the development of equipment for analysing continuously the various products manufactured, and where development work is also being carried on in many branches of physics including thermal conductivity, spectroscopy, optical absorption and electro-chemistry.

There are opportunities for progressive careers in the fields of instrument design and maintenance as well as in research and development.

Candidates should have a good Honours Degree but previous experience, though useful, is not essential.

The excellent conditions of service in the Company are well known and include Profit-Sharing and Pension schemes. Housing assistance also available for married men.

The I.C.I. salary scheme includes generous starting salaries which depend on age, qualifications and experience, and there is ample opportunity for subsequent advancement.

Applicants should apply in the first instance quoting Reference PR1.24 to:

**Staff Manager,
General Chemicals Division,
Cunard Building, Liverpool, 3**

Bulletin of The Institute of Physics

SCIENTIFIC OFFICERS

required by

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, ALDERMASTON, BERKSHIRE.
To undertake work in the field of electrical physics, devising novel items and proving their feasibility for special application.

1st or 2nd class honours degree in physics required. A working knowledge of electronics and experience in one or more of the following fields an advantage: gas discharges, detonation processes, solid state physics. Salary: To be assessed according to age, qualifications and experience within the scale £645-£1,120 p.a.

Contributory Superannuation Scheme. A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance.

Postcards for application forms to the Senior Recruitment Officer at above address. Please quote ref. 1640/110.

HIVAG LTD., a Company associated with a major group in the telecommunications field, requires scientific and technical staff to work on the development and production of valves, cold cathode tubes and similar products. Applications are invited from **PHYSICISTS, CHEMISTS and ENGINEERS**, having a degree or equivalent qualification and interested in these fields. Previous experience is not essential, except for the more senior appointments, for which the ability to work with the minimum of supervision is required. The posts are pensionable and offer considerable scope for advancement and vacancies are available at both Harrow-on-the-Hill and South Ruislip. Applications, which will be treated in strict confidence, should be addressed: The Engineer-in-Chief, Hivac Ltd., Stonefield Way, Victoria Road, South Ruislip.

SOUTH EAST ESSEX TECHNICAL COLLEGE AND SCHOOL OF ART

LONGBRIDGE ROAD, DAGENHAM, ESSEX.

Required in January, or as soon afterwards as possible: Lecturer in Physics or Electrical Engineering (light current), mainly for classes in electronics and telecommunications engineering for C.G.L.I. and H.N.C. courses. Candidates should hold a University degree in either physics or electrical engineering with teaching and/or industrial experience. Salary: £1,200 x £30-£1,350 plus London allowance (£36 or £48). Details and application forms (stamped addressed foolscap envelope) from the Clerk to the Governors at the College.

Several attractive and Senior Positions are offered in the Development and Industrial application of modern non-destructive testing techniques. The positions will be in the following fields:

- (1) Electronic Circuit Development
- (2) Properties of Materials
- (3) Physical Investigation and Measurement

They offer good scope to men of initiative and experience in the above fields. Salaries will be commensurate with the candidate's qualifications and experience.

Applications should be made in writing in the first instance, giving full details of qualifications, previous experience, age and salary required to: Personnel Manager, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex.